CHAPTER 6. ENERGY USE DETERMINATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 6. ENERGY USE DETERMINATION

6.1 INTRODUCTION

To carry out the life-cycle cost (LCC) and payback period (PBP) calculations described in Chapter 8, DOE needed to determine the operating cost savings to consumers from more-efficient equipment. The LCC and PBP analysis requires data on annual energy use because, along with energy prices, DOE uses these data to establish the most significant component of consumer operating costs. (Maintenance and repair costs are the other contributors to operating cost.) This chapter describes how DOE determined the annual energy consumption of residential electric and gas ranges and microwave ovens and how more-efficient equipment impacts annual energy consumption.

The technical support document (TSD) for DOE's notice of proposed rulemaking (NOPR) covered conventional cooking products (i.e., cooktops and ovens), microwave oven energy factor (EF), microwave oven standby power consumption, and commercial clothes washers (CCW).[1] This chapter presents information and results pertaining solely to conventional cooking products and microwave oven EF. The impact of more-efficient equipment on microwave oven standby power and CCWs will be addressed in subsequent TSDs.

6.2 COOKING PRODUCTS

6.2.1 Cooktops and Ovens

The annual energy consumption of electric and gas ranges has been in continual decline since the late 1970s. DOE's 1996 technical support document (TSD) identified several studies that estimated the annual energy consumption of electric and gas ranges.[2] The studies that covered the time period of 1977–1992 showed a steady decline in the annual energy consumption. More recent studies from the 2004 California Residential Appliance Saturation Study (CA RASS)[3] and the Florida Solar Energy Center (FSEC)[4] show a continued decline in the annual energy consumption. The studies seem to confirm that the U.S. populace is eating out more frequently and cooking less at home.

6.2.1.1 Average Annual Energy Consumption

Based on the research conducted for the 1996 TSD, DOE published revisions to its test procedure as a final rule in 1997 that included a reduction in the annual useful cooking energy output and a reduction in the number of self-cleaning oven cycles per year.[5] The annual useful cooking energy output relates the energy factor of the cooking appliance to the annual energy consumption.

For electric cooktops, the annual energy consumption (E_{CA}) is determined based on the following DOE test procedure equation:

$$E_{CA} = \frac{O_{CT}}{Eff_{CT}}$$

where:

O_{CT} = 173.1 kilowatt-hours (kWh) per year, annual useful cooking energy output, and
Eff_{CT} = Cooktop efficiency, which is also equivalent to the cooktop energy factor.

For gas cooktops, the following DOE test procedure equation is used to determine the annual energy consumption:

$$E_{CA} = \frac{O_{CT}}{R_{CT}}$$

where:

O_{CT} = 527.6 thousand British thermal units (kBtu) per year, annual useful cooking energy output, and
R_{CT} = Cooktop energy factor.

Note that the annual energy consumption for gas cooktops does not account for any electrical energy consumption. The DOE test procedure implicitly assumes that any electrical energy consumption in a gas range is allocated to the oven rather than the cooktop. The test procedure also implicitly assumes that stand-alone, built-in gas cooktops do not consume electrical energy.

For electric self-cleaning and non-self-cleaning ovens, the following DOE test procedure equation is used to determine the total annual energy consumption (E_{AO}):

$$E_{AO} = \frac{O_O}{R_O}$$

where:

O_O = 29.3 kWh per year, annual useful cooking energy output, and
R_O = Oven energy factor.

For gas self-cleaning and non-self-cleaning ovens, the annual energy consumption is composed of gas energy (E_{AOG}) and electrical energy (E_{AOE}). The following DOE test procedure equation is used to determine the total annual energy consumption:

$$E_{AOG} + E_{AOE} \times K_e = \frac{O_O}{R_O}$$

where:

O_O = 88.8 kBtu per year, annual useful cooking energy output,
R_O = Oven energy factor, and
K_e = 3,412 Btu/kWh, conversion factor for kWh to Btus.

Based on the baseline energy factors established in DOE's 1996 TSD for cooking products, the annual energy consumption of electric and gas cooktops and ovens can be determined using the above DOE test procedure equations. Table 6.2.1 shows the associated annual energy consumption based on the 1996 TSD cooktop and oven energy factors. The table also presents the baseline cooking efficiencies. Note that the cooking efficiencies are lower than the energy factors due to the energy used by components that are not dedicated to cooking food (e.g., clock power, self cleaning). DOE considers the annual energy consumption values to be representative of electric and gas cooking energy usage circa the mid-1990s.

Table 6.2.1 Annual Energy Consumption of Baseline Electric and Gas Cooktops and Ovens Based on DOE Test Procedure Energy Use Calculations

Product Type	Baseline Cooking Efficiency*	Baseline Energy Factor*	Annual Energy Consumption
Electric Cooktop**	74.0%	0.740	234 kWh
Gas Cooktop***	39.9%	0.156	3382 kBtu
Electric Standard Oven (Non-Self-Cleaning)	12.15%	0.1066	274 kWh
Electric Self Cleaning Oven	13.79%	0.1099	305 kWh
Gas Standard Oven (Non-Self-Cleaning)***	5.92%	0.0298	2960 kBtu
Gas Self-Cleaning Oven†	7.13%	0.0540	1644 kBtu

* Baseline cooking efficiencies and energy factors from DOE, Cooking Product TSD, 1996. Energy factor for electric standard ovens in 1996 TSD reflects 7 self-cleaning cycles; corrected to reflect 4 self-cleaning cycles.

** Energy Factor is the weighted-average of the baseline values for coil (73.7%) and smooth (74.2%) cooktops.

*** Annual energy consumption reflects the use of standing pilots in the baseline products.

† Annual energy consumption does not account for electrical energy consumption.

DOE identified two additional studies that confirmed the continued downward trend in electric and gas range energy use: (1) the 2004 CA RASS and (2) a 2001 study conducted by FSEC. The CA RASS reported an average electric range annual energy consumption of 263 kWh per year while the FSEC study reported an average electric range annual energy consumption of 300 kWh per year, both of which are lower than the consumption values derived from the DOE test procedure for a non-self-cleaning range (234 + 274 = 508 kWh) and a self-cleaning range (234 + 305 = 539 kWh). The CA RASS also reported an average gas range

annual energy consumption of 43 therms (4300 kBtu) per year, but the study did not identify whether the energy use value was associated with ranges equipped with standing pilots.

Using the data from the studies in the 1996 TSD, the CA RASS, and FSEC, Figure 6.2.1 and Figure 6.2.2 show how the annual energy consumption of electric ranges and gas ranges, respectively, have varied over time. The figures indicate whether the estimates came from metered studies or conditional demand analyses. The figures below demonstrate that the annual energy use of cooking products has continued to decline over time. As a result, DOE believes that an electric range annual energy consumption of 281.5 kWh per year (the average of the CA RASS and FSEC studies) is more representative of baseline annual energy use than that derived from the DOE test procedure.

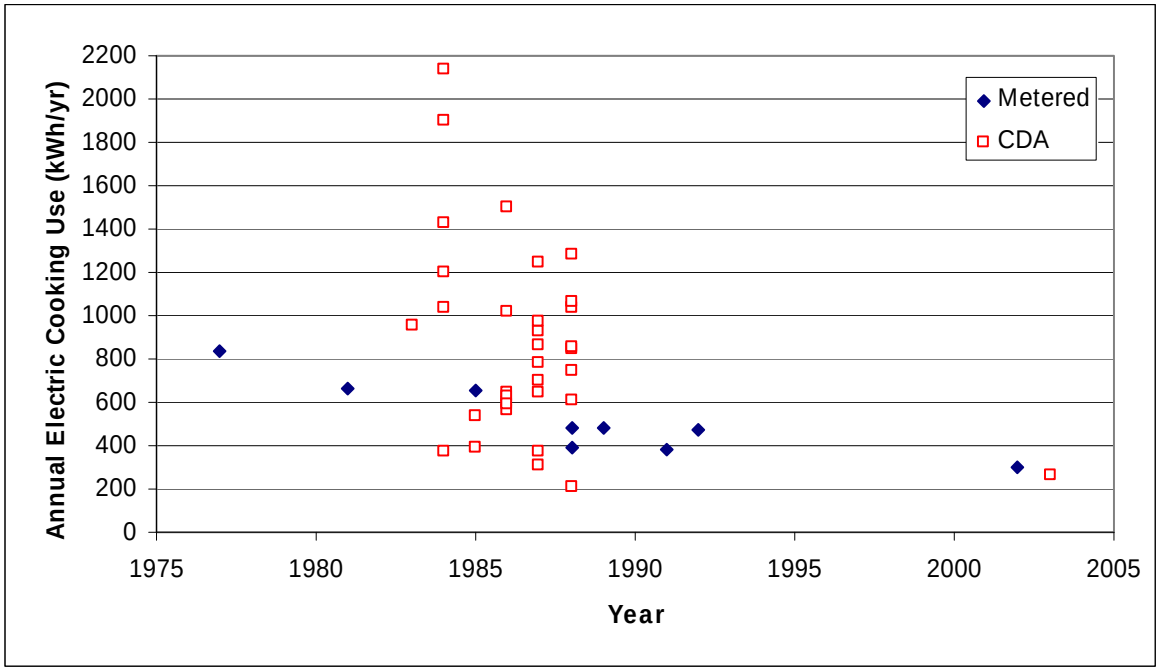

Figure 6.2.1 Historical Estimates of Annual Electric Range Energy Use

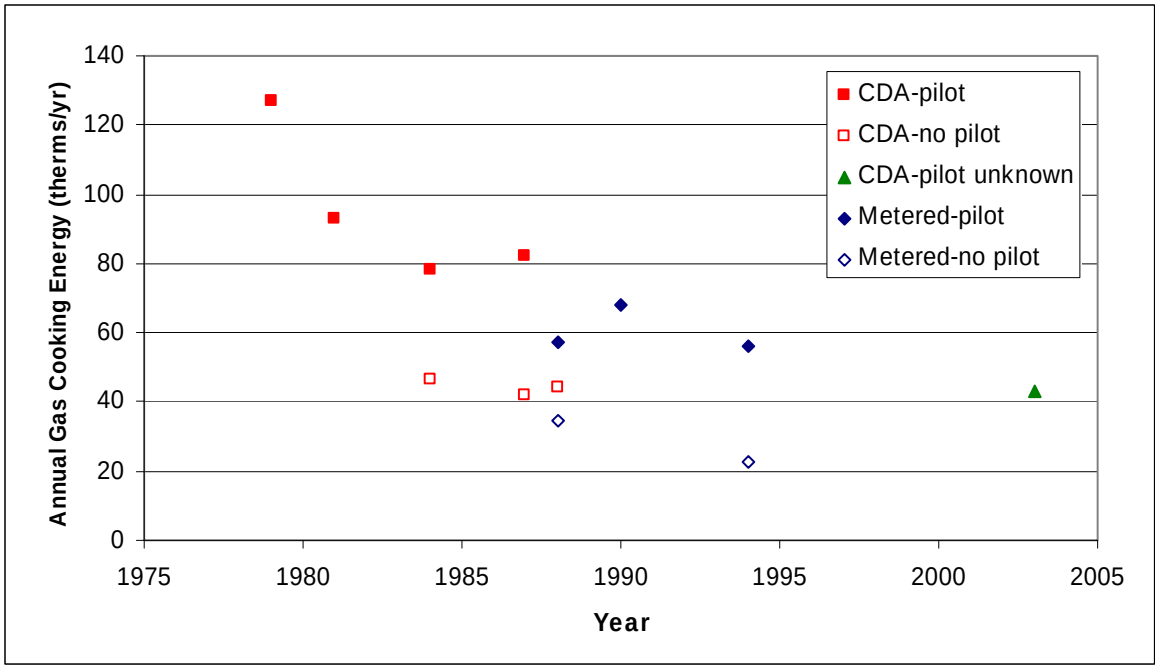

Figure 6.2.2 Historical Estimates of Annual Gas Range Energy Use

6.2.1.2 Annual Energy Consumption of Energy-Using Components

DOE performed several calculation steps to disaggregate the representative baseline average annual energy consumption value for an electric range (281.5 kWh per year) into appropriate energy use values for the various energy-using components of electric and gas cooktops and ovens. The calculations are presented in Appendix 6A. Table 6.2.2 shows the results of these calculations. In the table, DOE presents the energy use values for electric and gas cooktops, standard ovens, and self-cleaning ovens with their disaggregated energy use components (i.e., cooking, ignition, self-cleaning, and clock) that correspond to the baseline cooking efficiencies provided in DOE's 1996 TSD (see Table 6.2.1). Note that, because the annual useful cooking energy output values based on the updated annual energy use data are lower than those in the current DOE test procedure, the energy factors for each cooktop and oven are lower than those shown in Table 6.2.1.

Table 6.2.2 Component Annual Energy Use of Baseline Cooktops and Ovens

Energy Use Components	Cooktops			Ovens				
				Electric		Gas		
	Electric	Gas with pilots	Gas w/o pilots	Standard	Self-Cleaning	Std with pilot	Std w/o pilot	Self-Cleaning
Cooking								
Efficiency	74.0%	39.9%	39.9%	12.15%	13.79%	5.92%	5.92%	7.13%
Electric (kWh/yr)	128.2			132.4	116.6			
Gas (MMBtu/yr)		0.72	0.72			0.82	0.82	0.68
Self-Cleaning								
Electric (kWh/yr)					21.1			0.7
Gas (MMBtu/yr)								0.17
Ignition								
Electric (kWh/yr)							21.1	21.1
Gas (MMBtu/yr)		2.02				1.01		
Clock (kWh/yr)				34.2	33.3			31.5
Total	128.2 *kWh*	2.74 *MMBtu*	0.72 *MMBtu*	166.5 *kWh*	171.0 *kWh*	1.83 *MMBtu*	0.92* *MMBtu*	1.04* *MMBtu*
Annual Useful Cooking Energy Output	94.8 *kWh*	289.1 *kBtu*	289.1 *kBtu*	16.1 *kWh*	16.1 *kWh*	48.7 *kBtu*	48.7 *kBtu*	48.7 *kBtu*
Energy Factor	0.740	0.106	0.399	0.097	0.094	0.027	0.053	0.047

* Total reflects electrical energy consumption converted to MMBtu.

6.2.1.3 Annual Energy Consumption by Efficiency Level

As discussed in Chapter 5, for the purposes of developing the cost-efficiency relationships of electric and gas range cooking products, DOE analyzed only those efficiency levels from its 1996 TSD. The following tables present the annual energy consumption of electric and gas range cooking products by efficiency level. DOE based the baseline annual energy consumption for each cooking product on the 'total' values shown in Table 6.2.2.

Table 6.2.3 and Table 6.2.4 show the electric cooktop energy factors and their corresponding annual energy consumption. Because there is no additional energy use beyond what is needed for cooking, the energy factor for electric cooktops is equivalent to the cooking efficiency. The baseline annual energy consumption of 128.2 kWh is taken from Table 6.2.2. DOE determined the annual energy consumption for a more efficient level by taking the ratio of the energy factors of the more efficient and baseline levels and multiplying it by the baseline annual energy consumption.

Table 6.2.3 Electric Coil Cooktops: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Annual Energy Consumption
		kWh/year
Baseline	0.737	128.2
1	0.769	122.9

Table 6.2.4 Electric Smooth Cooktops: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Annual Energy Consumption
		kWh/year
Baseline	0.742	128.2
1	0.753	126.3

Table 6.2.5 shows the gas cooktop energy factors and cooking efficiencies as well as their corresponding annual energy consumption. Note that the energy factors provided in Table 6.2.5 are based on the DOE test procedure's annual useful cooking energy output rather than the value based on more recent annual energy consumption data. The baseline annual energy consumption of 2.74 million Btu (MMBtu) is taken from Table 6.2.2 and consists of two components: cooking energy (i.e., energy used to cook food) and standing pilot energy. The baseline annual energy consumption assumes that the cooktop is equipped with two standing pilots. The first efficiency level corresponds to the elimination of standing pilots. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption.

Table 6.2.5 Gas Cooktops: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Cooking Efficiency	Cooking	Pilot*	Total
			MMBtu/year	*MMBtu/year*	*MMBtu/year*
Baseline	0.156	39.9%	0.72	2.02	2.74
1	0.399	39.9%	0.72	-	0.72
2	0.420	42.0%	0.69	-	0.69

* Pilot light consumption based on the use of two pilot lights that each use 115 Btu/hr.

Table 6.2.6 shows the electric standard (non-self-cleaning) oven energy factors and cooking efficiencies as well as their corresponding annual energy consumption. Note that the energy factors provided in Table 6.2.6 are based on the DOE test procedure's annual useful cooking energy output rather than the value based on more recent annual energy consumption data. The baseline annual energy consumption of 149.9 kWh is taken from Table 6.2.2 and consists of two components: cooking energy and clock energy. The clock energy is based on a power consumption of 3.9 Watts. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that clock energy remains constant with increased efficiency.

Table 6.2.6 Electric Standard Ovens: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Cooking Efficiency	Cooking	Clock†	Total
			kWh/year	*kWh/year*	*kWh/year*
Baseline	0.1066	12.2%	132.4	34.2	166.5
1	0.1113	12.8%	125.9	34.2	160.1
2	0.1163	13.4%	119.7	34.2	153.9
3	0.1181	13.7%	117.6	34.2	151.8
4	0.1206	14.0%	70.7	34.2	149.0
5	0.1209	14.1%	70.6	34.2	148.6

† Clock energy consumption based on clock power of 3.9 Watts.

Table 6.2.7 shows the electric self-cleaning oven energy factors and cooking efficiencies as well as their corresponding annual energy consumption. Note that the energy factors provided in Table 6.2.7 are based on the DOE test procedure's annual useful cooking energy output rather than the value based on more recent annual energy consumption data. The baseline annual energy consumption of 155.3 kWh is taken from Table 6.2.2 and consists of three components: cooking energy, self-cleaning energy, and clock energy. The self-cleaning energy is based on data from DOE's 1996 TSD, i.e., a consumption of 5.286 kWh per self-cleaning cycle. There are four self-cleaning cycles per year. The clock energy is based on a power consumption of 3.8 Watts. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that both self-cleaning and clock energy remain constant with increased efficiency.

Table 6.2.7 Electric Self-Cleaning Ovens: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Cooking Efficiency	Cooking	Self-Clean*	Clock**	Total
			kWh/year	*kWh/year*	*kWh/year*	*kWh/year*
Baseline	0.1099	13.8%	116.6	21.1	33.3	171.0
1	0.1102	13.8%	116.2	21.1	33.3	170.6
2	0.1123	14.2%	113.5	21.1	33.3	167.9

* Self-cleaning energy consumption based on 5.286 kWh/cycle and 4 self-cleaning cycles per year.

** Clock energy consumption based on clock power of 3.8 Watts.

Table 6.2.8 shows the gas standard oven energy factors and cooking efficiencies along with their corresponding annual energy consumption. Note that the energy factors provided in Table 6.2.8 are based on the DOE test procedure's annual useful cooking energy output rather than the value based on more recent annual energy consumption data. The baseline annual energy consumption of 1.83 MMBtu is taken from Table 6.2.2 and consists of two components: cooking energy and standing pilot energy. The baseline annual energy consumption assumes that the oven is equipped with one standing pilot. The first and seventh (i.e., '1a') efficiency

levels correspond to the elimination of the standing pilot. The first efficiency level is based on the use of a globar or hot surface ignition device that, based on data from DOE's 1996 TSD, has a test energy consumption of 176 Watt-hr. Efficiency level '1a' is based on the use of an electronic ignition or spark ignition device that, according to DOE's 1996 TSD, uses a negligible amount of electricity. Because the use of a globar ignition device is the technology most commonly used to eliminate the need for a standing pilot, efficiency levels two through six follow efficiency level '1' as opposed to level '1a'. Efficiency levels four through six include the use of a forced-convection fan. Based on data from DOE's 1996 TSD, the convection fan has a test energy consumption of 15 Watt-hr. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that the ignition energy remains constant with increased efficiency.

Table 6.2.8 Gas Standard Ovens: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Cooking Efficiency	Cooking*		Ignition**		Total	
			MMBtu/yr	*kWh/yr*	*MMBtu/yr*	*kWh/yr*	*MMBtu/yr*	*kWh/yr*
Baseline	0.0298	5.9%	0.82	-	1.01	-	1.83	0.0
1***	0.0536	5.8%	0.84	-	-	21.1	0.84	21.1
2	0.0566	6.1%	0.80	-	-	21.1	0.80	21.1
3	0.0572	6.2%	0.79	-	-	21.1	0.79	21.1
4	0.0593	6.5%	0.75	1.8	-	21.1	0.75	22.9
5	0.0596	6.5%	0.75	1.8	-	21.1	0.75	22.9
6	0.0600	6.6%	0.74	1.8	-	21.1	0.74	22.9
1a***	0.0583	5.8%	0.84	-	-	-	0.84	0.0

* Electrical energy consumption for cooking due to forced convection fan. Measured test energy use of 15 W-hr.

** Gas energy consumption for ignition based on use of one pilot light that uses 115 Btu/hr.
Electrical energy consumption for due to hot surface ignition device. Measured test energy use of 176 W-hr.

*** For gas standard ovens, levels 1 and 1a correspond to designs that are utilized for the same purpose—eliminate the need for a standing pilot—but the technologies for each design are different. Level 1 is a hot surface ignition device while level 1a is a spark ignition device. Standard level 1a is presented at the end of the table because standard levels 2 through 6 are derived from standard level 1.

Table 6.2.9 shows the gas self-cleaning oven energy factors and cooking efficiencies along with their corresponding annual energy consumption. Note that the energy factors provided in Table 6.2.9 are based on the DOE test procedure's annual useful cooking energy output rather than the value based on more recent annual energy consumption data. The baseline annual energy consumption of 0.86 MMBtu and 39.3 kWh is taken from Table 6.2.2 and consists of several components: cooking energy, self-cleaning energy, ignition energy, and clock energy. The baseline annual energy consumption assumes that the oven uses a globar or hot surface ignition device which, based on data from DOE's 1996 TSD, has a test energy consumption of 176 Watt-hr. All efficiency levels include the use of a forced convection fan. Based on data from DOE's 1996 TSD, the convection fan has a test energy consumption of 15 Watt-hr. The self-cleaning energy is based on data from DOE's 1996 TSD, namely, gas consumption of

43,158 Btu and electrical consumption of 0.171 kWh per self-cleaning cycle. There are four self-cleaning cycles per year. The clock energy is based on a power consumption of 3.6 Watts. DOE determined the annual cooking energy consumption for a more efficient level by taking the ratio of the cooking efficiencies of the more efficient and baseline levels and multiplying it by the baseline annual cooking energy consumption. DOE assumed that the self-cleaning, ignition, and clock energy remain constant with increased efficiency.

Table 6.2.9 Gas Self-Cleaning Ovens: Annual Energy Consumption by Efficiency Level

Level	Energy Factor	Cooking Effcy	Cooking*		Self-Clean**		Ignition***	Clock†	Total	
			MMBtu/yr	*kWh/yr*	*MMBtu/yr*	*kWh/yr*	*kWh/yr*	*kWh/yr*	*MMBtu/yr*	*kWh/yr*
Baseline	0.0540	7.1%	0.68	-	0.17	0.7	21.1	31.5	0.86	53.3
1	0.0625	8.8%	0.56	1.8	0.17	0.7	21.1	31.5	0.73	55.1
2	0.0627	8.8%	0.55	1.8	0.17	0.7	21.1	31.5	0.73	55.1
3	0.0632	8.9%	0.55	1.8	0.17	0.7	21.1	31.5	0.72	55.1

* Electrical energy consumption for cooking due to forced convection fan. Measured test energy use of 15 W-hr.

** Self-cleaning energy consumption based on gas use of 43,158 Btu/cycle, electrical use of 0.171 kWh/cycle, and 4 self-cleaning cycles per year.

*** Electrical energy consumption due to hot surface ignition device. Measured test energy use of 176 W-hr.

† Clock energy consumption based on clock power of 3.6 Watts.

6.2.1.4 Variability of Annual Energy Consumption

DOE's Energy Information Administration (EIA) conducts a Residential Energy Consumption Survey (RECS) that collects energy-related data for occupied primary housing units in the U.S. The 2001 RECS collected data from 4,822 housing units representing almost 107 million households.[6] The RECS indicates which households in the survey use electric and gas ranges, ovens, and cooktops. With regard to electric cooking products, 2895 household records have cooktops, 1159 household records have standard ovens, and 1601 household records have self-cleaning ovens. With regard to gas cooking products, 1597 household records have cooktops in either electric ranges or as stand-alone units, 959 household records have standard ovens, and 494 household records have self-cleaning ovens. The above totals represent cooktops and ovens in households as either a stand-alone unit or as part of a range.

Although RECS does not provide the annual energy consumption of the cooking product for each household record, it does provide the frequency of cooking use. Thus, DOE can utilize the frequency of use to define the variability of the annual energy consumption. Conducting the analysis in this manner captures the observed variability in annual energy consumption while maintaining the average annual energy consumption shown above in section 6.4.2 in Table 6.2.2. To determine the variability of cooking product energy consumption, DOE first equated the weighted-average cooking frequency from RECS with the average energy use values reported in Table 6.2.2. Table 6.2.10 presents the weighted-average cooking frequency values along with the corresponding annual energy use values from Table 6.2.2.

Table 6.2.10 Annual Energy Use of Baseline Cooktops and Ovens with corresponding RECS Cooking Frequency

	Cooktops			Ovens				
				Electric		Gas		
	Electric	Gas with pilots	Gas w/o pilots	Standard	Self-Cleaning	Std with pilot	Std w/o pilot	Self-Cleaning
Annual Energy Consumption	128.2 *kWh*	2.74 *MMBtu*	0.72 *MMBtu*	166.5 *kWh*	171.0 *kWh*	1.83 *MMBtu*	0.92 *MMBtu*	1.04 *MMBtu*
RECS average cooking frequency *(meals per day)*	1.22	1.29	1.29	0.52	0.57	0.49	0.49	0.56

DOE then varied the annual energy consumption for each RECS household based on its reported cooking frequency. DOE determined the annual cooking energy consumption for each RECS household with a cooktop based on the following equation:

$$E_{CA\_HH} = Freq_{C\_HH} \times \frac{E_{CA\_AVG}}{Freq_{C\_AVG}}$$

where:

E_{CA_HH} = Cooktop annual energy consumption for specific RECS household,
$Freq_{C\_HH}$ = Cooktop frequency for specific RECS household,
E_{CA_AVG} = Average cooktop annual energy consumption (from Table 6.2.10); 128.2 kWh for electric cooktops; 2.74 MMBtu for gas cooktops with pilots; and 0.72 MMBtu for gas cooktops without pilots, and
$Freq_{C\_AVG}$ = Average cooktop frequency (from Table 6.2.10); 1.22 meals/day for electric cooktops; and 1.29 meals per day for gas cooktops.

DOE determined the annual cooking energy consumption for each RECS household with an oven based on the following equation:

$$E_{AO\_HH} = Freq_{O\_HH} \times \frac{E_{AO\_AVG}}{Freq_{O\_AVG}}$$

where:

E_{AO_HH} = Oven annual energy consumption for specific RECS household,
$Freq_{O\_HH}$ = Oven frequency for specific RECS household,
E_{AO_AVG} = Average oven annual energy consumption (from Table 6.2.10); 149.9 kWh for electric standard ovens; 155.3 kWh for electric self-cleaning ovens; 1.83 MMBtu for gas standard ovens with pilots; 0.96 MMBtu for gas standard ovens without pilots; and 0.99 MMBtu for gas self-cleaning ovens, and

$Freq_{O\_AVG}$ = Average oven frequency (from Table 6.2.10); 0.52 meals/day for electric standard ovens; 0.57 meals/day for electric self-cleaning ovens; 0.49 meals/day for gas standard ovens; and 0.56 meals per day for gas self-cleaning ovens.

For all RECS households, cooktop and oven cooking frequency varies between zero to four meals per day. Figures 6.4.3 through 6.4.8 show the probability distributions of annual cooking energy consumption based on correlating the average cooking energy use to the cooking frequency data from RECS.

Figures 6.4.3 and 6.4.4 show the distribution of electric and gas cooktop energy use, respectively. For gas cooktops, critical to the determination of the distribution of annual energy consumption is the determination of which cooktops have standing pilots. Based on shipments data from the 1996 TSD, the only cooktops that still have standing pilots are in gas ranges without self-cleaning ovens (i.e., gas standard ranges). In other words, all stand-alone cooktops and gas ranges with self-cleaning ovens have pilotless ignition systems. Based on estimates from the Appliance Recycling Information Center, approximately 250,000 standard gas ranges (or approximately 20 percent of gas standard range shipments) were sold in 2004 with standing pilots.[7] Of the gas cooktops in RECS households, 43 percent are either in stand-alone units or in self-cleaning gas ranges while 57 percent are in standard gas ranges. Therefore, for purposes of defining which RECS households with gas cooktops utilize standing pilots, DOE assumed that 20 percent of the standard gas ranges, or 11 percent of all gas cooktops, are equipped with standing pilots.

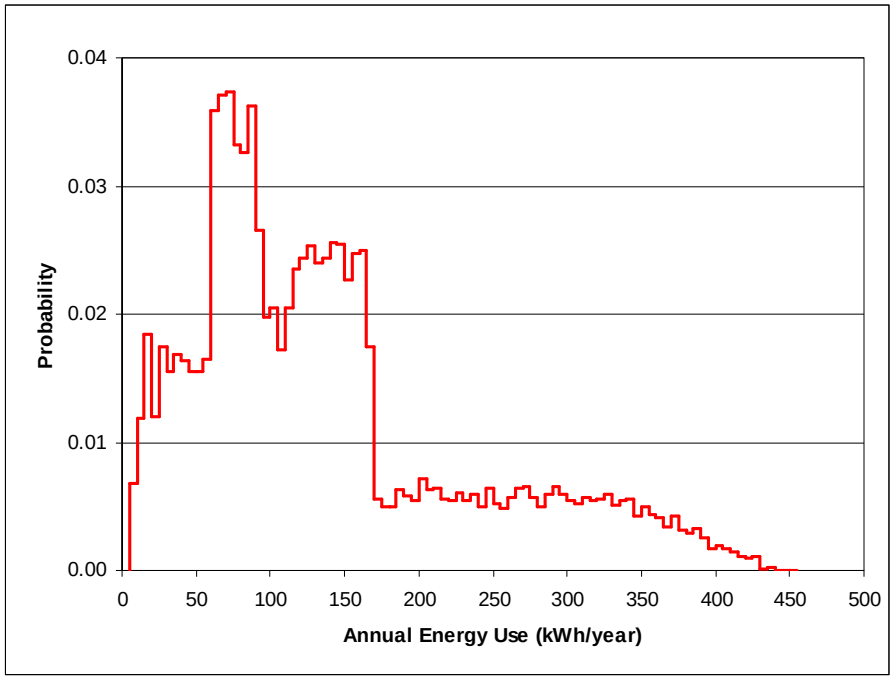

Figure 6.2.3 Distribution of Baseline Electric Cooktop Annual Energy Use Based on 2001 RECS Cooking Frequency

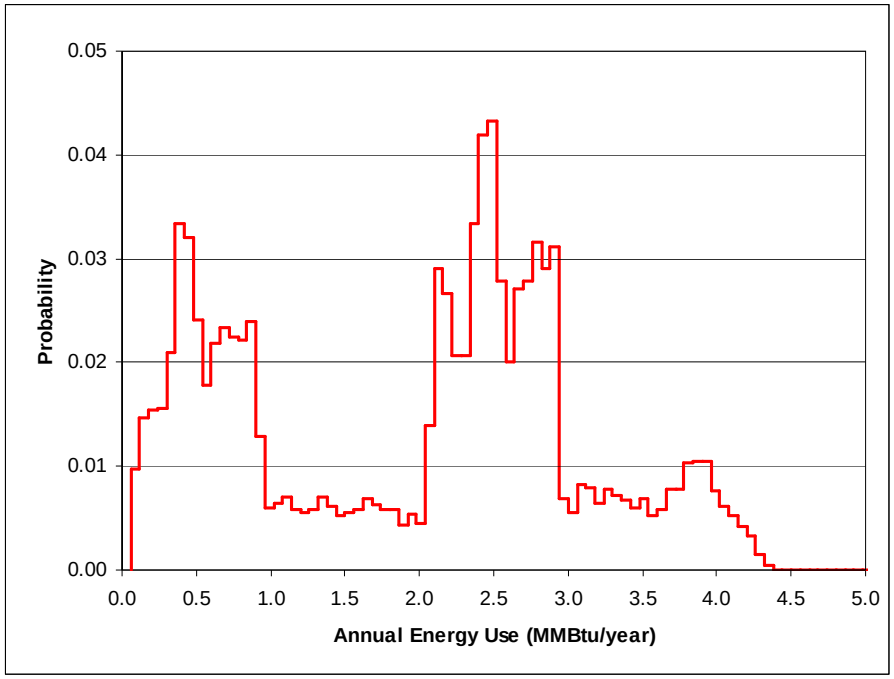

Figure 6.2.4 Distribution of Baseline Gas Cooktop Annual Energy Use Based on 2001 RECS Cooking Frequency

Figures 6.4.5 and 6.4.6 show the distribution of annual energy use for electric standard and self-cleaning ovens, respectively.

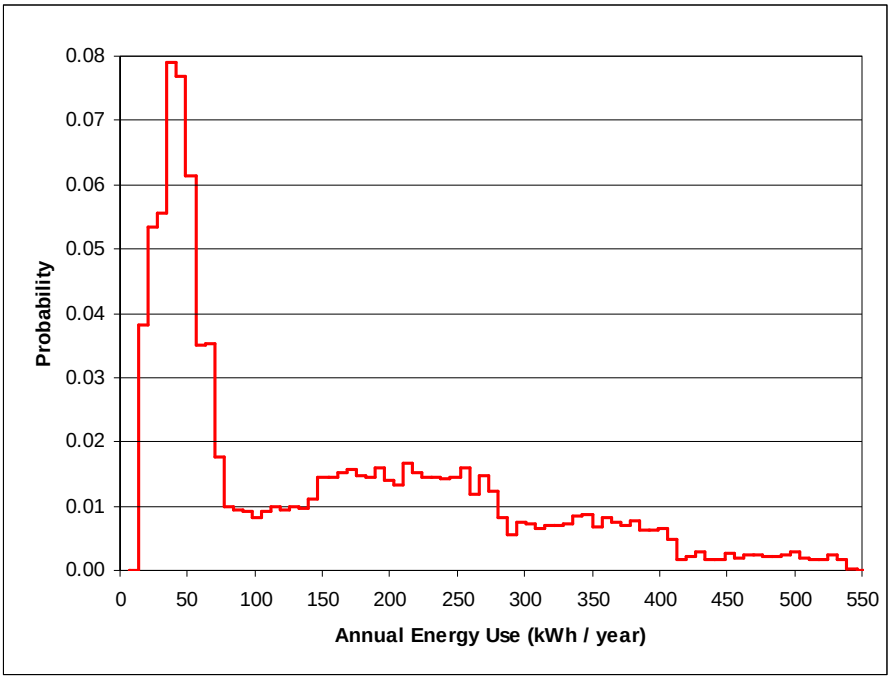

Figure 6.2.5 Distribution of Baseline Electric Standard Oven Annual Energy Use Based on 2001 RECS Cooking Frequency

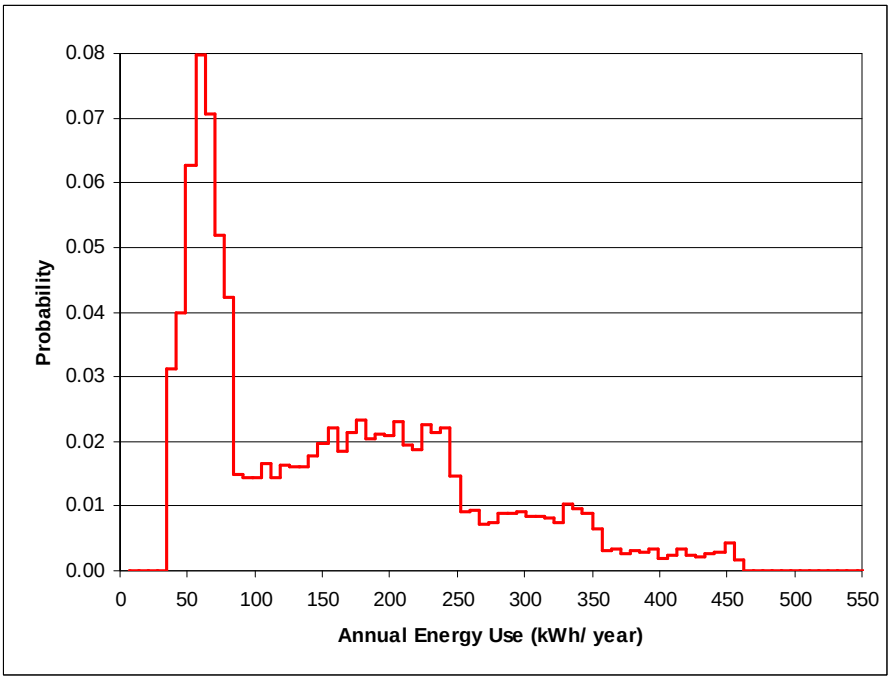

Figure 6.2.6 Distribution of Baseline Electric Self-Cleaning Oven Annual Energy Use Based on 2001 RECS Cooking Frequency

Figures 6.4.7 and 6.4.8 show the distribution of annual energy use for gas standard and self-cleaning ovens, respectively. For gas ovens, critical to the determination of the distribution of annual energy consumption is the determination of which ovens have standing pilots. Based on shipments data from the 1996 TSD, the only ovens still equipped with standing pilot are in gas ranges without self-cleaning ovens (i.e., gas standard ranges). In other words, all stand-alone cooktops and gas ranges with self-cleaning ovens have pilotless ignition systems. As stated above for gas cooktops, based on estimates from the Appliance Recycling Information Center, approximately 250,000 standard gas ranges (or approximately 20 percent of gas standard range shipments) were sold in 2004 with standing pilots. Of the gas standard ovens in RECS households, only four percent are in built-in units while 96 percent are in standard gas ranges. Therefore, for purposes of defining which RECS households with gas ovens use standing pilots, DOE assumed that 20 percent of standard gas ranges, or 19 percent of all gas standard ovens, are equipped with standing pilots.

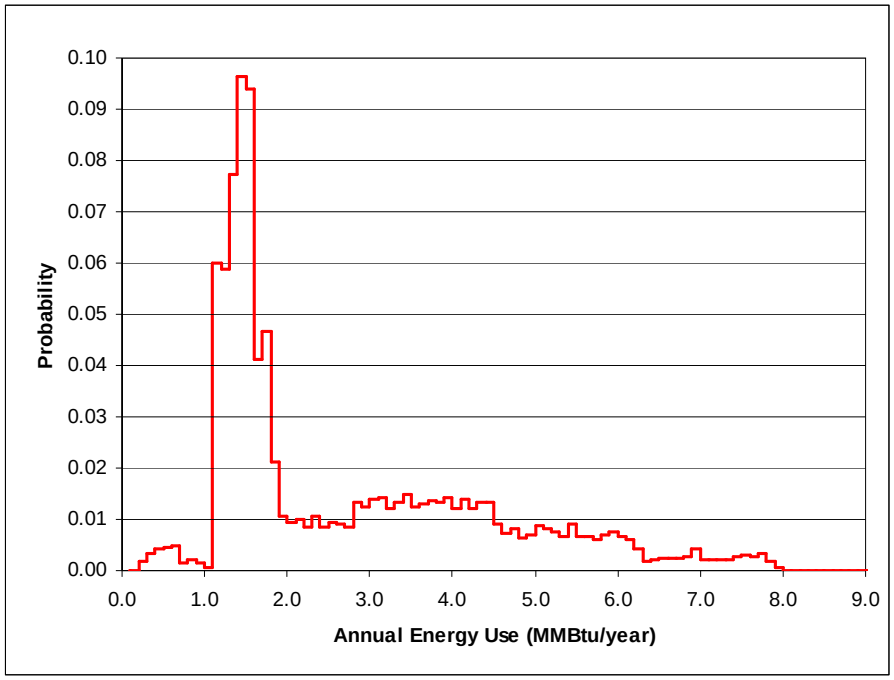

Figure 6.2.7 Distribution of Baseline Gas Standard Oven Annual Energy Use Based on 2001 RECS Cooking Frequency

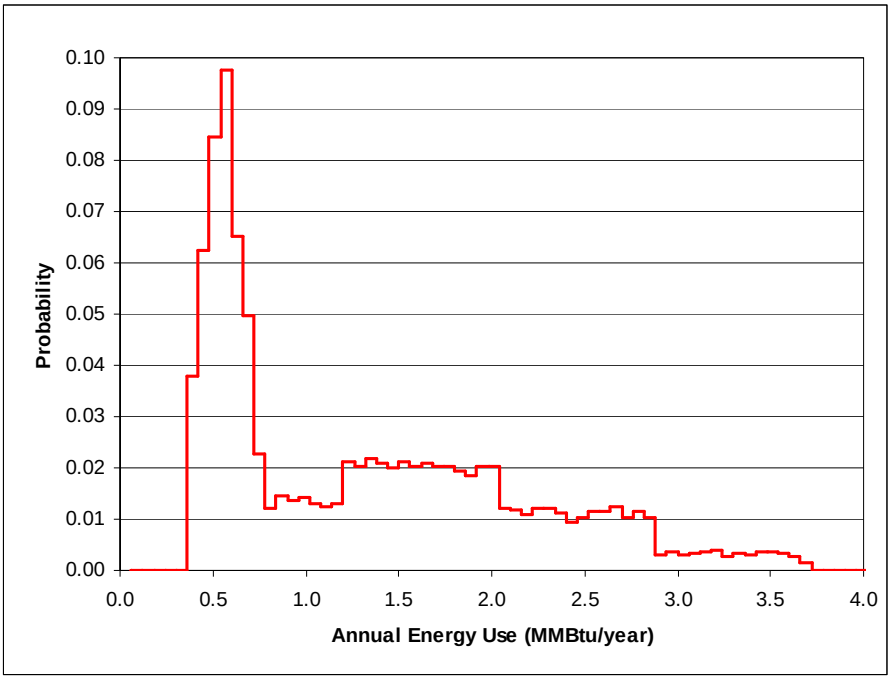

Figure 6.2.8 Distribution of Baseline Gas Self-Cleaning Oven Annual Energy Use Based on 2001 RECS Cooking Frequency

As will be described later in Chapter 8 on the LCC and PBP analysis, DOE used the RECS household samples with their associated baseline annual cooking energy consumption to conduct the LCC and PBP analysis.

6.2.2 Microwave Ovens

After microwave oven annual energy consumption increased from the late 1970s to the late 1980s, annual energy consumption has remained relatively steady since the late 1980s. DOE's 1996 TSD identified studies that estimated the annual energy consumption of microwave ovens. With the exception of one study based on the use of conditional demand analysis, the studies, which covered the time period 1988–1994, showed that annual energy consumption was no more than 200 kWh per year. A more recent study from the 2004 CA RASS is in line with the results from the previous studies.

6.2.2.1 Average Annual Cooking Energy Consumption

Based on the research conducted for the 1996 TSD, DOE published revisions to its test procedure for microwave ovens as a final rule in 1997 that included an increase in the annual useful cooking energy output.[5] The annual useful cooking energy output relates the energy factor of the cooking appliance to the annual energy consumption. The annual energy consumption (E_{MO}) is determined based on the following DOE test procedure equation:

$$E_{MO} = \frac{O_M}{R_{MO}}$$

where:

O_M = 79.8 kWh per year, annual useful cooking energy output, and
R_{MO} = Microwave oven energy factor.

Based on a microwave oven baseline energy factor of 55.7 percent that DOE established in its 1996 TSD, the annual energy consumption of microwave ovens can be determined using the above DOE test procedure equation. DOE considers the resulting annual energy consumption of 143.2 kWh per year to be representative of microwave oven energy usage circa the mid-1990s.

As with electric and gas range cooking products, DOE's 1996 TSD also identified several studies estimating the annual energy consumption of microwave ovens. The CA RASS reported an average microwave annual energy consumption of 131 kWh per year. Figure 6.2.9 shows the annual energy consumption for microwave ovens based on the studies from the 1996 TSD and the CA RASS. The figure plots the reported annual energy use values from the studies by year and indicates whether the estimates came from metered studies, conditional demand analyses, or a combination of the two. Microwave oven energy use has remained relatively steady. Although the DOE test procedure produces an annual energy consumption that is close to that indicated by CA RASS, DOE believes that the value of 131 kWh per year is a more representative energy use value. Based on an annual energy consumption of 131 kWh per year and a baseline energy factor of 55.7 percent, DOE lowered the annual useful cooking energy output to 73.0 kWh per year.

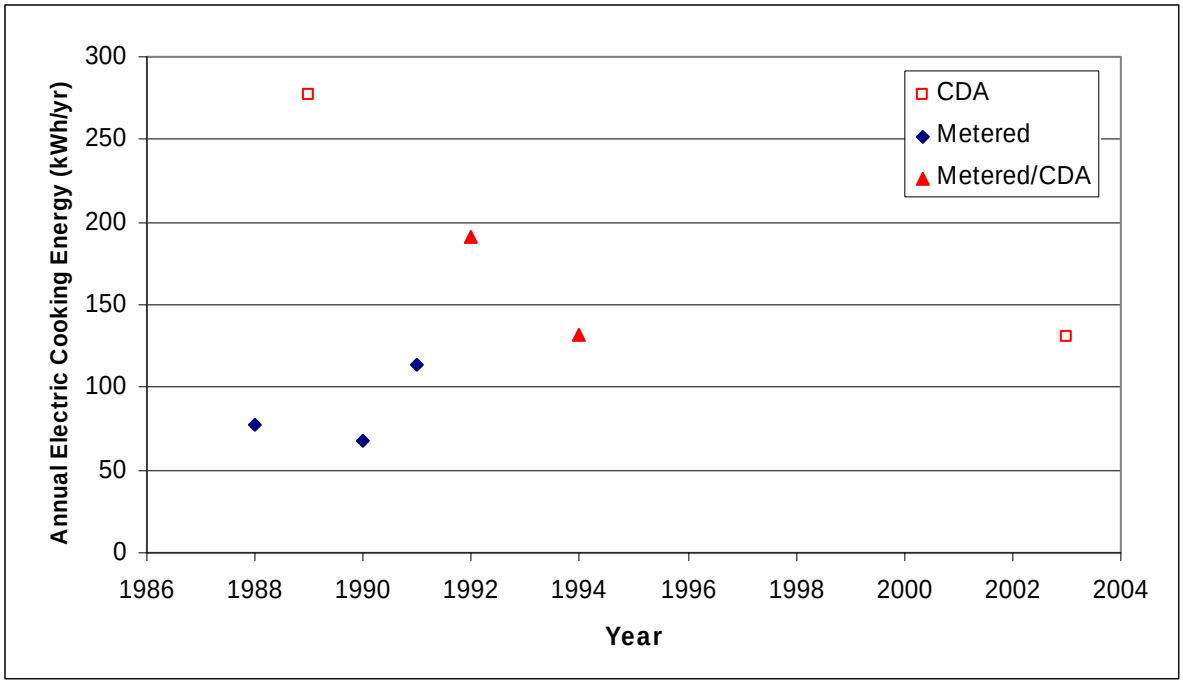

Figure 6.2.9 Historical Estimates of Annual Microwave Oven Energy Use

6.2.2.2 Standby Power Energy Consumption

As discussed in Section 3.14.3 of Chapter 3, Market and Technology Assessment, during the course of DOE's investigation of microwave oven standby power consumption, DOE and AHAM tested a combined total of 52 units. Based on these tests, DOE determined the percent at each of the standby power levels identified in the engineering analysis (see Chapter 5). Since no other data were available, DOE used the test data to develop the market shares of standby power consumption. As shown in Table 6.2.11, DOE developed a weighted-average standby power consumption associated with a baseline EF microwave oven.

Table 6.2.11 Microwave Ovens Standby Power Consumption

Market Share	Standby Power (W)
46.2%	4.0
34.6%	2.0
19.2%	1.5
0%	1.0
0%	0.02
Weighted-Average	**2.83**

To estimate the annual energy use associated with standby power (E_{SP}), DOE used the following expression where the baseline standby power is multiplied by the number of hours in a year the oven is in standby mode:

$$E_{SP} = P_{SP} \times Hours_{SP}$$

where:

P_{SP} = Standby power consumption (watts), and
$Hours_{SP}$ = Hours in a year the microwave oven is in standby mode (kWh/yr).

The annual standby hours equals the total hours in a year minus the number of hours the microwave oven is in active operation. DOE determined the hours of active operation ($Hours_{ACTIVE}$)with the following expression:

$$Hours_{ACTIVE} = \frac{E_{MO}}{I_{MO}}$$

where:

E_{MO} = annual (cooking) energy consumption, and
I_{MO} = Microwave input power (watts).

As discussed in Chapter 5, DOE and AHAM tested a total of 52 microwave ovens as part of its analysis to determine how display and sensing technologies impact standby power consumption. From that testing, the average output power of the 52 tested units equaled 1026 watts. The corresponding input power is based on the following expression:

$$I_{MO} = \frac{O_{MO}}{R_{MO}}$$

where:

O_{MO} = Microwave output power (watts).

Based on the baseline microwave EF of 0.557 and an average output power of 1026 watts, the average input power is 1842 W. Therefore, based on an annual cooking energy consumption of 131 kWh/year, there are 71 hours of active operation, resulting in 8689 hours that the appliance is in standby mode.

Based on a four watt standby power, the annual standby power energy consumption equals 24.5 kWh per year.

6.2.2.3 Annual Energy Consumption by Efficiency Level

As discussed in Chapter 5, for the purposes of developing the cost-efficiency relationships of microwave ovens, DOE used the efficiency levels from its 1996 TSD.

Table 6.2.12 shows how the annual energy consumption varies by microwave oven energy factor. The baseline annual energy consumption is 155.6 kWh. DOE determined the annual cooking energy consumption of a more efficient level by taking the ratio of the more efficient and baseline cooking efficiencies and multiplying it by the baseline annual energy consumption.

Table 6.2.12 Microwave Ovens: Annual Energy Consumption by Energy Factor Level

Level	Energy Factor	Cooking Consumption		Standby Power Consumption		Total Energy Consumption
		Efficiency	Energy Use	Standby Power	Energy Use*	
			kWh/year	*W*	*kWh/year*	*kWh/year*
Baseline	0.557	55.7%	131.0	2.83	24.6	155.6
1	0.586	58.6%	124.5	2.83	24.6	149.1
2	0.588	58.8%	124.1	2.83	24.6	148.7
3	0.597	59.7%	122.2	2.83	24.6	146.8
4	0.602	60.2%	121.2	2.83	24.6	145.8

* Annual standby power energy consumption based on 8689 standby hours per year.

6.2.2.4 Variability of Annual Cooking Energy Consumption

The 2001 RECS indicates that 4,149 of the 4,822 households in the survey use microwave ovens. Although RECS does not provide the annual cooking energy consumption of the microwave ovens, it does provide the frequency of use. Thus, DOE can utilize the frequency of use to define the variability of the annual energy consumption. Conducting the analysis in this manner captures the observed variability in annual energy consumption while maintaining the average energy consumption value. To determine the variability of microwave oven energy consumption, DOE first equated the weighted-average cooking frequency from RECS with the average cooking energy use value of 131 kWh per year. The weighted-average cooking frequency from RECS is 0.40 meals per day. DOE then varied the annual energy consumption for each RECS household based on its reported cooking frequency. DOE determined the annual cooking energy consumption for each RECS household with a microwave oven based on the following equation:

$$E_{MO\_HH} = Freq_{MO\_HH} \times \frac{E_{MO\_AVG}}{Freq_{MO\_AVG}}$$

where:

E_{MO_HH} = Microwave oven annual energy consumption for specific RECS household,
$Freq_{MO\_HH}$ = Microwave oven frequency for specific RECS household,
E_{CA_AVG} = Average microwave oven annual cooking energy consumption of 131 kWh, and
$Freq_{C\_AVG}$ = Average microwave oven frequency of 0.40 meals/day.

For all RECS households, microwave oven cooking frequency varies between zero to four meals per day. Figure 6.2.10 shows the probability distribution of annual cooking energy consumption based on correlating the average cooking energy use to the cooking frequency data from RECS.

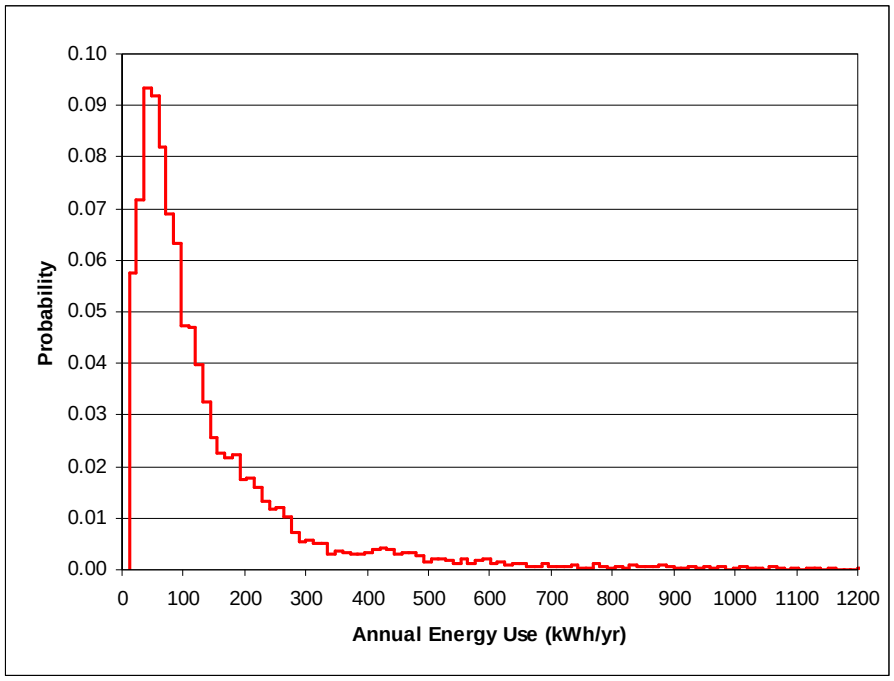

Figure 6.2.10 Distribution of Microwave Oven Annual Cooking Energy Use Based on 2001 RECS Cooking Frequency

As will be described later in Chapter 8 on the LCC and PBP analysis, DOE used the RECS household samples with their associated baseline annual cooking energy consumption to conduct the LCC and PBP analysis.

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